Program Progress Performance Report
for University Transportation Centers

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Research and Innovative Technology Administration
UTC Program

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Signature: [Signature]
Major Goals and Objectives of the Program

Research, Development, Deployment
The CMU-Penn T-SET UTC focuses on safety. Our research is specifically targeted at improving the safety of automotive drivers and passengers, bicyclists and pedestrians, and the safe usage of trucks and mass transit vehicles.

The thrusts of the T-SET UTC are structured along 5 core areas: In-Vehicle Technologies, Infrastructure Technologies, Human-Vehicle Interactions, Mobility/Data Analytics and Policy.

Metrics:
- Faculty scientific leadership as reflected by the number of publications and citations of faculty work in transportation-related areas;
- The number of staff, faculty and students involved in leadership positions in academic, industry and government transportation organizations;
- New research collaborations in fields related to this work;
- Successful technology deployments and their impact; and
- Patents and start-ups.

Education and Workforce Development
Education and workforce development are important complements of the T-SET research program.

Metrics:
- Number of transportation-related courses,
- Students participating in transportation research projects,
- Advanced degree programs funding T-SET UTC students,
- T-SET UTC-funded graduate students,
- T-SET UTC-funded students who receive degrees,
- Institutional educational partnerships, and
- Participants in workforce and educational programs.

Technology Transfer
The CMU-Penn UTC will fully use the resources and the experience of these university centers to promote enterprises arising from its research program. Faculty who already created startups in the past, serve as mentors to colleagues interested in this activity.

Metrics:
- Simple adoption of the innovation by a transportation operator, company or public, to more formalized outcomes such as licensing, patents, commercialization, and spin-off companies.
- Quantify numbers of meetings, attendance, publications, and social media and website activity.

Collaboration
Collaboration is the heart of the entire T-SET program. CMU and Penn seek to ensure our research and development program leads to deployment of technologies in the transportation systems serving our communities and state, providing pilot applications for global use. The CMU-Penn team will collaborate with related centers on the two campuses, state and local public partners, non-profit community partners and industry partners.
- Number and diversity of members of both the T-SET Consortium and Advisory Council, and by the
Number and impact of deployments achieved through collaboration

Accomplishments Under Major Goals

See Appendix A for specific research project accomplishments.

Research, Development and Deployment

T-SET’s major accomplishment for the period of reporting was hosting the 2nd Annual UTC Safety Summit. There were 65 participants including 14 UTCs and national representatives from government, industry and community groups. USDOT Assistant Secretary, Greg Winfree, was the lunch keynote speaker.

Other Research, Development and Deployment activities include:

• Attended NRC Pathways to Sustainability Committee Meeting
• Attended Volpe-Cylab Meeting on Vehicle Cybersecurity
• Attended TRB Special Projects and Policy Committee
• Attended NRC FHWA R&D Oversight
• Attended PA Turnpike Project Scoping Meeting for Mobility Analytics and Accident Reconstruction
• Hosted Postmaster General Visit to CMU to discuss Road Surface Monitoring and Automated Vehicles
• Research Presentation to PennDOT District 11
• University of Pittsburgh Transportation Forum
• Meeting with CEO of the Pittsburgh Parking Authority for Data Sharing
• Met with Bike Pittsburgh to discuss bicycle detection met with Matt Baumann, PHD at Pitt to discuss bicycle detection
• Met with the Airport to discuss future research opportunities
• Brought Researchers to Pitt Ohio facility to discuss research opportunities
• Met with Butler county to discuss freight prioritization
• Meeting with Mapillary to discuss partnership

Education and Workforce Development

During this reporting period, we established a new Women in Transportation Summer Scholars Fellowship for undergraduates in partnership with the Robotics Institute, became active members in Women’s Transportation Seminar Transportation U activities, focused efforts on expanding the programming of the Transportation Club, and partnered with PennDOT on workforce development.

Education and workforce development activities include:

• Meeting in State College PA of the Pennsylvania Consortium of Transportation Universities
• Hosted a student tour at Google offices in Pittsburgh
• Guest Lecture at Master of Urban Design Course
• Meeting with Student Starting AASHE Student Chapter r
• Heinz College Capstone Advisory Committee for Autonomous Shuttle
• Heinz College Capstone Advisory Committee for Airport disabled travelers
• Hosted Vinn White Presentation at the Heinz College
• Hosted 4 T-SET faculty meetings
  Hosted first event in series of Tranportation Tech Nights, Bike Hack Night: Speed Monitoring
• Meeting with Aimee Jefferson regarding Transportation You

Technology Transfer & Collaboration

UTC Consortium Meeting was held on November 12, 2015 at Carnegie Mellon University. The consortium meeting featured a research and deployment fair, where community, government and other partners could meet our researchers and learn more about their research.

Other Technology Transfer and Collaboration Activities include:
• Faculty Seminar Presentation: Kari Watkins, visiting faculty from Georgia Tech presented work on OneBusWay, an open source platform for real time transit information. For those who were not able to attend, the presentation was live streamed and uploaded to our Learning Channel.
• Seminar Presentation. Corey Harper presented on Estimating Safety and Costs and Changes in Vehicle Miles Traveled from Vehicle Automation. For those who were not able to attend, the presentation was live streamed and uploaded to our Learning Channel.
• Faculty Seminar Presentation: Greg Barlow presented on Surtrac Updates and What’s Next for the Adaptive Traffic Signal Systems. For those who were not able to attend, the presentation was live streamed and uploaded to our Learning Channel.
• Deployment Seminar Presentation: Lee Haller from Pittsburgh DPW joined CMU faculty member Steve Smith to present on snow plow routing in the City of Pittsburgh.
• Meeting with CIE regarding Enterpreneur In Residence collaboration
• Attended the Regional Data Center Kick-off
• Attended Northwestern - Trans. Institute Review
• Attended ASCE Editors Workshop
• Attended Pittsburgh Smart City Planning workshop
• Traveled to Singapore to hold meetings with Singapore Management University
• Traveled to Adelaide to hold meeting with Carnegie Mellon Adelaide Australia Campus
• Facilitated Pittsburgh Smart City Challenge Partner Charrette
• Attended UTC/CUTC Winter Meeting
• Hosted Leadership Pittsburgh Class Visit to CMU
• Hosted Smart City Council Jesse Bearst Visit to CMU
• Hosted SAE Visit to CMU
• Hosted Verizon Visit to CMU
• Attended Meeting with Coalition to Support Inner City Rail
• Attended Meeting with Director of the Pittsburgh SBA Office
• Meeting with CEO of the Southwestern PA Commission to discuss Mobility Analytics
• Meeting with the Allegheny Conference on Community Development to discuss Mobility Analytics
• Speak at the International Bridge Tunnel and Turnpike Association Transportation Policy and Finance Summit
• Hosted Mayor Peduto Smart City Challenge Press Event at CMU
• Attended ITS World Congress in Bordeaux, France
• Sat on Panel at the American Archetectual Foundaiton Forum on Automated Vehicles
• Exhibited in the ITS America Capitol Hill Technology Showcase
• Keynote speaker at Dinner Meeting of the SWPA Chapter of ASHE
• Attended TRB UTC Spotlight Conference on Connected and Autonomous Vehicles
• Hosted PNC visit to CMU
• Attended ITSA Board Meeting
• Presented at Penn State Transportation Safety and Engineering Conference
• Sponsored Greater Pittsburgh Chamber of Commerce Public Officials Reception
• Met with French autonomous vehicle company, Navya
• Attended Transit Geeks
• Attended SAFE Fifth Forbes Now Committee meeting
• Met with TomTom to discuss partnership with City of Pittsburgh

• Met with SPC regarding Road Safety Audits
• Met with McKees Rocks Community Group regarding Freight Prioritization
• Participated in Platform Pittsburgh meeting hosted by City of Pittsburgh
• Presented at AV Symposium Workshop at TRB
• Attended SXSW for Smart City Challenge events
• Participated in Smart City webinar for NOFO#2

Diversity
T-SET continues to push initiatives that support women in the intelligent transportation domain including:
• Supporting the Women in Transportation Fellow to attend TRB Annual Meeting
• Member of the board of Pittsburgh Chapter of the Women’s Transportation Seminar
• Member of the Northeast Regional Council of the Women’s Transportation Seminar
• Participated in WTS Scholarship Committee
• Sat on Women’s Forum Panel with Sec. Richards
• Held a meeting of the Women’s Graduates in Transportation Group
• Worked with WTS International on the Transportation YOU steering, leading the development of the challenge book for high school girls at the Transportation U event to be held in DC, summer 2016.

Products
General Program Products
• UTC website www.utc.ices.cmu.edu
• 5749 blog posts
• Consistent weekly distribution of T-SET email newsletter, 1,550 subscribers
• Continue to use a webinar-based system of linking CMU and UPenn faculty and students for our bi-monthly T-SET meetings. Now a faculty member interactively presents their research at the beginning of each meeting.
• Promotion of various CMU and Penn research news articles in the T-SET blog and newsletter
T-SET in the MEDIA

March 31, 2016 Pittsburgh Mayor Peduto in San Diego to pursue Smart City Challenge grant
March 25, 2016 CMU Study: autonomous vehicles could improve MPG 10% in EPA tests
March 24, 2016 CMU Featured in Sec. Foxx's Blog "Different Pathways Lead To Transportation Careers"
March 24, 2016 VIDEO: CMU "Eyes on the Road" video highlights Christoph Mertz's Road Surface Monitoring Work
March 23, 2016 Uber Wants to Be Hacked
March 18, 2016 NYT: Autonomous Cars Aren't Perfect, but How Safe Must They Be?
March 17, 2016 CONGRATS! Pittsburgh one the Smart City Challenge Finalists.
March 17, 2016 VIDEO: CMU’s Raj Rajkumar on Smart Cities
March 17, 2016 Driverless Cars Must Have Steering Wheels, Brake Pedals, Feds Say
March 9, 2016 After Uber exodus, Carnegie Mellon lands $11M in contracts
March 9, 2016 Federal policy reverses benefits of alternative fuel vehicles
March 4, 2016 Self-Driving Cars Are Coming, But They're Not Ready For Pittsburgh Yet
February 20, 2016 Uber considers building test track in Hazelwood
February 22, 2016 How TomTom is plotting a route into US driverless car industry
February 11, 2016 - INFOGRAPHIC: The Virtuous Cycle Between Driverless Cars, Electric Vehicles and Car-Sharing Services
February 11, 2016 - The Case for Making Self-Driving Cars Think Like Humans
February 11, 2016 - CMU Heinz College seeking Women in Transportation Fellow for Fall 2016
February 3, 2016 - CMU advances in high-speed ground transit competition
February 2, 2016 How Technology Is Helping the Blind Navigate the Physical World
January 28, 2016 - What will cheap gas do to electric cars?
January 28, 2016 - Uber Is Making Sure Those Bad Driver Ratings Are Correct
January 26, 2016 - Uber monitoring drivers in US in attempt to flag dangerous driving
January 26, 2016 - What will cheap gas do to electric cars?
January 26, 2016 - Uber monitoring drivers in US in attempt to flag dangerous driving
January 21, 2016 - Watch a Drone Helicopter Release a Driverless Ground Vehicle
January 21, 2016 - At Carnegie Mellon, a Futuristic Vision for Hyperloop, and the Finances to Match
January 20, 2016 - Pa. Turnpike, Waze app team to map out best routes
January 20, 2016 - NYT: For Now, Self-Driving Cars Still Need Humans
January 15, 2016 - The firms who will beat Google to get us into self-driving cars
January 12, 2016 - Apple registers car-related web addresses as vehicle rumours gather speed
December 31, 2015 - Newsmaker: Ramayya Krishnan
December 24, 2015 - Pittsburgh shines as beacon of opportunity for tech firms
December 24, 2015 - Driverless Cars Are Too Cautious for Chaotic Human Drivers
December 24, 2015 - Pittsburgh on the road to ‘inclusive innovation’
December 23, 2015 - The billion-dollar robot question — how can we make sure they’re safe?
December 17, 2015 - Boosting EVs with cloud power
December 17, 2015 - Why Hoverboards Keep Exploding
December 10, 2015 - 6 ways artificial intelligence is going to make your life better
December 10, 2015 - CMU student creates cool maps of Pittsburgh bike-share stats
December 3, 2015 - Why Aren’t Urban Planners Ready for Driverless Cars?
December 3, 2015 - CMU improving mobility: Making robotic prosthesis to help prevent falls in amputees
December 2, 2015 - Robots in the city: The future of automation
November 24, 2015 - An Innovation Case Study: Pittsburgh
November 12, 2015 - CMU Researcher’s Port Authority Sensors Help Smooth Your Ride Into Work
November 12, 2015 - The Dream Life of Driverless Cars
Appendix A - Research Projects Accomplishments, Products and Participants

**Enhanced pedestrian and vehicle detection using surround-view camera system**

PI: Vijayakumar Bhagavatula  
Co-PI(s): None  
Participant Organizations (deployment partners): General Motors  
Progress: 15%  
Technologies / Techniques: Computer vision algorithms for detection of road features such as road shoulders, concrete barriers and guard rail.  
Invention / Patent applications / Licenses: None  
Other Products associated: Software and video data base  
Please explain: We have setup a surround-view camera system on a vehicle and collected videos as the vehicle is being driven on highway. These videos contain relevant highway features such as road shoulders, guardrails, concrete barriers and soft shoulders that should be detected for autonomous driving. We have also labeled regions of these videos to indicate the locations of these road features in these videos.  
Impact: By using synchronized front-view and side-view camera videos provided a surround-view system, we should be able to more accurately identify the road features. More accurate identification of road features (such as road shoulders) should enable self-driving vehicles to maneuver into highway road shoulders in emergency situations.  
Impact in other disciplines: The computer vision algorithms, currently being developed for road feature detection, should be useful for other computer vision problems such as scene analysis.

**Infrastructure Monitoring from an In-Service Light Rail Vehicle**

PI: Jacobo Bielak  
Co-PI(s): Hae Young Noh (CEE), Jelena Kovačević (ECE)  
Participant Organizations (deployment partners): Port Authority of Allegheny County  
Other Collaborators: Jim Garrett (CEE), Pievincenzo Rizzo (Pitt)  
Progress: 90 Percent complete  
Journal publications  
Books or other non-periodical, one-time publications  
Other publications, conference papers and presentations  
G. Lederman, J. Bielak, H. Y. Noh, Rail monitoring from the dynamic response of a passenger train. Structural Health Monitoring Applications Case Study Archive.  
URL: https://sites.tufts.edu/shmcasestudies/  
Other Dissemination Activities
Lederman presented a talk on April 1st at “Forge: New Urban Frontiers,” the 2016 AIAS Northeast Quad Conference held at the Ace Hotel in Pittsburgh, PA. The conference was for architects to learn about technologies relevant to urban planning.

**Technologies / Techniques**

**Invention / Patent applications / Licenses**
We are working closely with CITEC to ensure the intellectual property is protected and disseminated. We have applied for one provisional patent and are following up with a full patent application.

**Other Products associated**
We have collected a large dataset (10TB) of train-based vibration data. We plan to make this public in the near future.

**Impact**
This reporting period, we proposed two new methods: a new sparse approach for analyzing data collected from trains, and a new data fusion approach for combining data from multiple trains. The first method provides a new way to analyze accelerometer recorded on a train by decomposing the signal into 1) the properties of the train and 2) the profile of the track. The second method could be important for monitoring tracks from crowd-sourced data. Rather than using data from a single high-quality sensor on a train, we can combine data from many low-quality sensors, such as sensors which may already exist on the vehicle. These two techniques will help to make track monitoring from in-service trains more practical.

This type of sensing, signal processing and data analysis could facilitate safer trains and more cost-efficient maintenance in the future. Moreover, the proposed approach is quite general and could be extended to other parts of the infrastructure, including bridges.

**Impact in other disciplines**
We have worked on incorporating new signal processing techniques into our work (like Sparse Representation) that we are publishing in civil engineering forums, which may further encourage collaboration between civil engineering and signal processing.

**Accident Investigation with 3D Models from Images**
PI Christoph Mertz

**Participant Organizations (deployment partners)**
City of Pittsburgh Police Department
TTI (Texas Transportation Institute)

**Other publications, conference papers and presentations**
Invited to present work at WREX 2016 (May 2016)

**Other Dissemination Activities**
Detailed instruction on how to do 3D accident reconstructions on website
Presentation of technology to:
2015:
Reconstruction Seminar (training for several hundred accident reconstruction officers)
CMU Transportation class
UTC consortium meeting
PNC visitors (among them Debbie Guild, Chief Technology Officer, PNC)
2016:
PTC (Pennsylvania Turnpike Commission, exploring possible joint projects)
Leadership Pittsburgh Traffic21 Site Visit
Pitt Ohio (truckin company)
Jesse Berst (Chairman at Smart Cities Council)
Sheffield Robotics (UK)
Congressman Keith Rothfus
SPC (South-Western Pennsylvania Commision)
Megan J. Brennan, Postmaster General
Website
http://www.cs.cmu.edu/~reconstruction/

Technologies / Techniques
The general technology is to take many (around 100) pictures of an accident scene and use software to create a 3D model of it. We further developed this to make it easier to use and more robust. So far we have concentrated on creating complete models of inside and outside a vehicle and of hard to reach areas like wheel wells.

Impact
This technology can drastically reduce the cost and time of 3D reconstruction for accident scenes. Current techniques involve $100k laser scanners. The cost of our technique is minimal. The sensor hardware is already standard equipment (cameras) and the software is free. The only costs are training and running the software.

Impact in other disciplines
3D reconstruction from images can be used in many other areas.

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Enhancing The Safety Of Visually Impaired Travelers In And Around Transit Stations
PI: M. Bernardine Dias

Participant Organizations (deployment partners):
- Western Pennsylvania School for Blind Children (WPSBC)
- Blind and Vision Rehabilitation Services of Pittsburgh (BVRSP)

Other Collaborators:
- Ermine Teves
- Eric Hochendoner
- Aaron Steinfeld

Website:
http://www.cs.cmu.edu/~navpal/

Technologies / Techniques:
Our work this year focused on hardening the NavPal app. We continued to explore a combination of WiFi and GPS-based indoor and outdoor localization, as well as our trusted sources framework for categorizing and utilizing accessible landmarks to enhance navigation.

Impact:
Findings from this work continue to impact several fields in useful ways. The trusted sources framework continues to receive interest from groups spanning non-profits and industry, and our prototype solution contributes to the state of the art in assistive technology research.

Impact in other disciplines:
While our focus is in the discipline of robotics, and more specifically in assistive technology, the outcomes of this work will also have impact in the fields of orientation and mobility (the
specialists who train blind and visually impaired people to navigate), accessible transportation, and human-computer interaction. Orientation and mobility experts continue to show interest in how our work can assist them to further enhance the independence and safety of blind and visually impaired people. Transportation groups such as Port Authority in Pittsburgh are interested in how this work can be used to improve the services they offer to riders with disabilities. Human-computer interaction researchers who focus on interface design are interested in what we learn about accessible interfaces to technology tools.

Low-Cost Vehicle Localization for Driving and Mapping
PI: John M. Dolan

Participant Organizations (deployment partners): GM R&D

Other publications, conference papers and presentations: Submitted the following paper to IEEE IROS 2016; decision to be announced in July 2016:


Other Dissemination Activities: Nothing to report

Website: http://www.ri.cmu.edu/research_project_detail.html?project_id=775&menu_id=261

Our current work is on reducing computation through focused sampling and minimal replanning; and generation of smooth trajectories across the range of highway, urban, and evasive maneuver scenarios. The motion planner requires high-accuracy localization.

Technologies / Techniques:
For autonomous vehicles, navigation systems must be accurate enough to provide lane-level localization. High-accuracy sensors are available but not cost-effective for production use. Although prone to significant error in poor circumstances, even low-cost GPS systems are able to correct Inertial Navigation Systems to limit the effects of dead reckoning error over short periods between sufficiently accurate GPS updates. Kalman filters are a standard approach for GPS/INS integration, but require careful tuning in order to achieve quality results. This creates a motivation for a Kalman filter which is able to adapt to different sensors and circumstances on its own. Typically for adaptive filters, either the process (Q) or measurement (R) noise covariance matrix of Kalman filters is adapted, and the other is fixed to values estimated a priori. We show that intelligently adapting both matrices in an intelligent manner can provide a more accurate navigation solution.

Other Products associated:
The described techniques for low-cost localization have been coded in C++ and tested in both closed-course and real-world scenarios in the Pittsburgh area, including the Oakland university neighborhood of Pittsburgh, which is a fairly dense urban environment.

Impact
The developed localization techniques are not yet sufficiently accurate to provide lane-level localization. However, in conjunction with odometry and map-matching, they have the potential to make it more cost-effective to provide localization for autonomous and semi-autonomous vehicles at an affordable price.

Impact in other disciplines
High-accuracy, low-cost localization for outdoor robots is a valuable technology that can be used for many other types of field robots besides autonomous cars.
Sensor-based Assessment of the In-Situ Quality of Human-Computer Interaction in Cars.
PI: SeungJun Kim
Co-PI(s): Anind K. Dey

Participant Organizations (deployment partners): Two academic institutions – CMU and UNIST (Ulsan National Institute of Science and Technology); Two automotive companies - TAKATA Holdings Inc. and Hyundai Motor Group; One international research institute - KETI (Korea Electronics Technology Institute); and One school of driving in the local area - Cindy Cohen School of Driving LLC

Other Collaborators
- More than 5 research fellows at CMU, HCI Institute, UbiComp Lab, led by Prof. Anind K. Dey (co-PI)
- Collaborators from the current non-CMU deployment partners, such as Dr. KyungTaek Lee and Dr. Hyo Seok Yoon (KETI, Contents Convergence Research Center), Prof. Ian Oakley (UNIST, Interaction Lab), Jung-Mi Park and Kye Yoon (Hyundai Motor Group – Human Factors and Device Research Team in the R&D division), Leonard S. Cech (TAKATA Corporation), Cindy Cohen (Cindy Cohen School of Driving, LLC)

Journal publications

Books or other non-periodical, one-time publications: Nothing to report

Other publications, conference papers and presentations

Other Dissemination Activities
- Invited talks (Dr. Kim) - The University of Alabama At Birmingham (UAB, Feb 17, 2016), Hyundai Motor Group (Apr 19, 2016), KETI Internet-of-Things Platform Research Center (Apr 20, 2016), KETI Contents Convergence Research Center (Apr 28, 2016)

Website
- UTC websites - Sensor-based Assessment of the In-Situ Quality of Human-Computer Interaction in the Cars (2016, active; http://utc.ices.cmu.edu/utc/projectitem.asp?ID=194)
- Other websites of the research team
  ○ PI and Co-PI research areas and details: Dr. SeungJun Kim (http://www.cs.cmu.edu/~sjunikim/) / Prof. Anind K. Dey (http://www.cs.cmu.edu/~anind/)
Project websites: Human-Vehicle Interaction (http://ubicomplab.org/project/human-vehicle-interaction-2/) / Multisensory Augmentation (http://ubicomplab.org/project/multisensory-augmentation/)

Technologies / Techniques
1. Human-vehicle interaction technology
2. Visual-analytic and machine-learning technology
3. Ubiquitous computing and sensor fusion technology in cars (focus: driver interruptibility)
4. User-centric automotive UI technology (focus: intelligent in-vehicle information systems)

Invention / Patent applications / Licenses
• Non-provisional application based on CMU Invention Disclosure 2015-396 on Sensor-based Assessment of Driver Interruptibility (by Dr. Kim, Prof. Dey, and Dr. Chun), in progress since Apr 2016.

Other Products associated + Please explain
• Video / Audio: Multimedia files collected during driving in the field
• Instruments or equipment: custom-built driving aware system
• Software: visual analytic tools for time-series sensor data

Impact
• Presented an enabling technology to operate sensing, computing, and feedback components together in a single mobile platform (e.g., an Android Tablet) that helps researchers deploy experiment testbeds in field driving experiments, reduce workloads of time-synchronization tasks across multiple sensors, and enable systems to trigger proactive feedback based on in-situ sensor data streams.
• Presented visual analytic tools that helps identify drivers’ routine behaviors and inspect multidimensional time-series sensor data streams.
• Generated new hypotheses for future works and new project items (e.g. new UTC proposal items, research contacts with Hyundai Motors Group, etc.).

Impact in other disciplines
• Has an impact in ubiquitous computing domain and human-computer interaction domain, especially on research related to real-time, objective assessment of cognitive load evoked by ubiquitous HCI demands.
• Presents a key enabling technology for creating human-in-the-loop cyber-physical systems that helps reduce users’ psychological distance to proactive intervention of cyber space that comes at a cost in cognitive engagement in physical space.

Stereoscopic Programmable Automotive Headlights for Improved Safety on the Road
PI Srinivasa Narasimhan, Robert Tamburo

Participant Organizations (deployment partners)
The National Robotics Engineering Center (NREC) is providing assistance with design work and prototype vehicle installation.

Technologies / Techniques
Hardware design for stereo headlights near completion—debugging of custom printed circuit board in progress. Software development underway for controlling two headlights. Installation of stereo prototype in a pick-up truck in progress (Fig. 1).
Non-intrusive Driver Fatigue and Stress Monitoring Using Ambient Vibration Sensing

PI: Hae Young Noh
Co-PI(s): Pei Zhang

Participant Organizations (deployment partners): Renault Innovation Silicon Valley
Other Collaborators: Pierre Delaigue from Renault
Other publications, conference papers and presentations

Other Dissemination Activities
1. We presented our work at Intel, February 2016.
2. We gave a seminar on this project at Lehigh University, Bethlehem, PA, April 2016.
3. We presented our work at Microsoft Research, May 2016.

Website

Technologies / Techniques
We are developing a driver fatigue and stress monitoring system using embedded accelerometers in car seats. These sensors can sense physiological states of the driver, such as movement, heart rate, and breathing, and then infer high level driver status, such as attention level and stress. Our algorithm combines analytical human model with data-driven approaches to reduce modeling uncertainties.

Impact
By monitoring the fatigue and stress level of the driver through the physiological variables, we enable the autonomous cars to understand the capability of the driver to take the control back in dangerous and/or unexpected situations.

Impact in other disciplines
Our research has impacts in many other disciplines. First, the development of our sensing system can be applied to other fields for non-intrusive indirect monitoring through vibration, such as wearable suits for muscle monitoring in sports activities, smart furniture to sense human activities, etc. Second, the inference algorithm to extract driver’s status from noisy vibration data can be applied to the areas, which requires signal decomposition to separate various components in the vibration measurements, such as vehicle-infrastructure interaction, manufacturing, infrastructure monitoring, etc. Third, we can understand the driver behaviors across different scenarios, which can be incorporated into car interface design and traffic management.

Pedestrian Detection for the Surtrac Adaptive Traffic System

PI: Bernardo Pires, Steve Smith
Co-PI(s): Greg Barlow

Participant Organizations (deployment partners)
City of Pittsburgh; Axis Communications AB

Other publications, conference papers and presentations
Mehmet Kocamaz, Jian Gong, Bernardo Pires, "Vision-based Counting of Pedestrians and Cyclists", IEEE Winter Conference on Applications of Computer Vision WACV’16, March 7-9, 2016, Lake Placid, NY, USA
Website
http://www.contrib.andrew.cmu.edu/~bpires/pedsSurtrac.html

Technologies / Techniques
Visual data collection and processing. Computer vision automatic detection of pedestrians and pedestrian intent to cross intersection. Tools for fast and assisted labeling of videos.

Other Products associated
Data & Research Material, Instruments or equipment, Software / Netware

Please explain
This project entails equipping one Surtrac intersection with cameras that will collect pedestrian activity and intent to cross intersection. For this purpose, we will collect and label public video data. We will also further develop data labeling software.

Impact
The objective of this project is to make Surtrac, the real-time adaptive traffic signal control system, aware of pedestrian traffic. Phase 1 of this one-year project will analyze pedestrian traffic at multiple Surtrac deployments. Phase 2 will focus on an intersection already equipped with Surtrac system in the Oakland / East Liberty region and will add additional sensing and processing capabilities to determine the presence of pedestrians waiting to cross the intersection.

Impact in other disciplines
In addition to the primary impact on transportation planning, this project will push forward the state of the art on the Computer Vision and Machine Learning Fields, by creating new classifiers tailored specifically to the bike and pedestrian detection problem, as well as a large body of classified visual data.

Integrating Transit Signal Priority with Adaptive Signal Control in a Connected Vehicle Environment

PI: Stephen F. Smith

Participant Organizations (deployment partners): Port Authority of Allegheny County

Journal publications:

Other publications, conference papers and presentations

Website: http://www.ozone.ri.cmu.edu/projects/traffic/

Technologies / Techniques
• Aggregate flow representation for transit priority – During the initial project period, an extension to the flow model of approaching traffic used by the Surtrac adaptive signal control system has been designed that incorporates knowledge of buses (as would be provided by connected vehicle technology) and provides a foundation for giving active attention and priority to transit vehicles. The new model uses estimates of the expected dwell time at
intervening bus stops to provide a more accurate indication of when an approaching bus will actually arrive at the intersection. Use of this extended model will enable the Surtrac intersection control algorithm to do a better job of optimizing green time allocation to match the bus’s movements.

**Impact:** The ability to detect buses (through V-to-I communication) and use this information to optimize green time allocation decisions will enable better on-time transit performance and improve the reliability of port authority transit schedules. It will also enable buses to move more efficiently through intersections nears side bus stops, which will have the side effect of boosting overall traffic flow efficiency since buses are often blocking progress of other vehicles. Finally, the techniques that are developed for transit priority can be transferred to expedite movements of trucks through intersections with similar performance benefits and provide a basis for freight prioritization.

**Impact in other disciplines:** Smart infrastructure such as CV-empowered traffic signal control is essential to future urban mobility, and an enabler of broader “smart cities” capabilities.

**Advanced driver distraction detection system**

**PI:** Fernando De la Torre

**Participant Organizations (deployment partners)**

General Motors

**Journal publications (related)**

F. Vicente, Z. Huang, X. Xiong, F. De la Torre, W. Zhang and D. Levi.

“Driver Gaze Tracking and Eyes Off the Road Detection System”,
IEEE Transaction on Intelligent Transportation Systems, Vol. 16, No 4, August 2015

**Other publications, conference papers and presentations**

Presentation on Federal Highway Administration May 12th 2016.

**Other Dissemination Activities**

Create videos to promote related technology for driver monitoring
https://www.youtube.com/watch?v=fpqzimW7HWg

**Website**

www.humansensing.cs.cmu.edu/intraface

Free software for facial image analysis. Had 400 downloads since March 1st 2016.

**Technologies / Techniques**


**Other Products associated**

Software

**Please explain**

We are collecting a dataset to provide ground truth of the measurements where the driver is looking on the road, in addition we plan to record driver’s activities.

**Impact**

Advanced Driver Assistance Systems (ADAS) is key technology to avoid crashes. This advanced system can potentially help to save many people’s lives.

**Impact in other disciplines**

In addition to computer vision, the basic mathematical computation for rotation estimation can be applied to other disciplines such as computer graphics.
Monitoring and Predicting Pedestrian Behavior at Traffic Intersections

PI: Luis E. Navarro-Serment

Co-PI(s): Martial Hebert

Participant Organizations (deployment partners): Rapid Flow Technologies, LLC

Other Dissemination Activities: Presentation to students at UVM, Mexico.

Technologies / Techniques: Vision-based pedestrian detection system, which is the basis for monitoring pedestrians. A key objective is to develop a robust system without a stringent demand for high-end cameras. Our work has focused on the use of vision sensors currently available at traffic intersections, used by SURTRAC. We are developing detection approaches that synergistically combine different elements to detect humans from low-resolution images, and under sub-optimal operation conditions.

Other Products associated: Pedestrian Awareness Library

Please explain: We are creating a software library which encapsulates the capabilities described above. This software will facilitate the deployment of pedestrian-awareness modules at each intersection.

Impact: Adaptive traffic light control systems such as SURTRAC currently do not take pedestrian traffic into account. Our work will enable these systems to make decisions based on a more complete representation of the world, resulting in better traffic management.

Impact in other disciplines: Pedestrian data can be used by other researchers to learn and discover patterns of human activity at multiple locations across the city.